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GENERAL SCIENCE.—*Science and the after-war period.*[1]

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Somewhat more than a year ago it was my privilege to address the Philosophical Society of Washington on the subject *Science and warfare in France*[2] in which I endeavored to indicate in some small measure the rôle science was playing in the war we all hope has just been brought to a close.

At this time, may we not consider the transition period into which we are entering and ask ourselves what will be the effect of war on science, the men of science, and in the relations of science to the community and the state? What are some of the lessons this war has taught? And what plans have been made here and elsewhere to apply them?

A scientific man would hardly be so rash as to pose as a prophet, yet he may, nevertheless, try to assemble and pass in review some of the tendencies of the time; and it is only by an intelligent examination of the underlying changes which are being produced in science and in its relation to society, that he is enabled to see his way ahead a little more clearly into the mist of the future; and he may thereby be enabled, at least in some small degree, to chart his course and take advantage of the various currents that have been set in motion by the war.

[1] Address of the retiring President of the Philosophical Society of Washington, presented before the Society January 4, 1919.

[2] Scientific Monthly, October, 1917.

The question may here be asked, can we not see from previous wars what this war will bring forth, or at least the broad lines along which progress will be made, in science and in its relation to mankind? But with what previous war shall we compare this? Surely not with the short Franco-German war of 1870 in which but two nations were engaged; if with the world-wide wars of the French revolution and Napoleon, we have a duration of twenty-five years as compared with four; and if any war prior to that epoch is considered, the development of science was hardly in a state to form a basis of comparison.

Again it may be asked, does war, did this war, stimulate scientific progress? Viewing the wealth of application of science in modern warfare, you will probably unhesitatingly say, *Yes*, but if you undertake to make a list of fundamental, new scientific principles developed as a war reaction I believe you will be embarrassed to name even a few of them; although there have been, of course, hundreds, nay, thousands, of applications of known scientific principles to new uses. It is still too soon, however, to estimate the scientific advance during the war and as caused by the war and such, even though I were competent, is not my purpose here. It will evidently be impossible to treat adequately the subject *Science and the after-war period* except in a most summary manner and I shall have to limit myself to certain phases in which I have been interested, paying particular attention to the physical sciences and the relation of science to industry.

SCIENTIFIC PRODUCTION

What is the effect of the war on scientific production, is not an easy question to answer. Many men have been killed, including a few who are scientific producers and many more young men who might have become distinguished in science; furthermore, not a few scientific centers have been destroyed. Thus viewed, there would appear to be a net loss to science in the world, but at the same time there have been stimulated to greater endeavor a considerable number of men of scientific ability and many new laboratories have been established. I believe that, for the

United States, the effect of the war will not have been detrimental to scientific production as our losses in young men of scientific attainments have been relatively insignificant, and also, I firmly trust, the country has in part learned the lesson of the advantage to the nation of generously supporting research.

For a country such as France, which has borne the brunt of the fighting for four years—and not until after the first battle of the Marne was any effort made to conserve her scientific men—the matter appears to be much more serious; but who dares to predict that the United States with nearly three times her population will lead France as a producer of original ideas in science a generation hence? It is well to remember that many of the master minds in science of the nineteenth century were born during the Napoleonic wars, and that it is quality and not quantity that counts in scientific progress.

Finally one may ask, is the after-war period to be one of great scientific activity or one of relative quiet, and what will be the lines along which development will take place? This brings us to a consideration of the nature and permanence of war activities in science. Never before have science and scientific men been used to such an extent both relatively and absolutely as the servants of war, both in the military establishments proper and in the not less important industrial supports. It is evident that what is beneficial in these relations should be maintained. In addition to the advancement in scientific knowledge, much of which is not yet generally available, brought into being by the war, there has also been worked out for war purposes, in a more or less satisfactory way, schemes of cooperation of scientific men with each other, with the state, with industry, and with the military establishment. Some of these are transitory in character, others are serviceable for both peace and war, and some have been devised especially for the after-war period.

One might perhaps expect a certain relaxation of effort, even among scientific workers, following the strenuous efforts of the war, but one must not forget the natural zest of the scientific man to get back to his chosen field which he will want to culti-

vate in his own way and not under the more or less arbitrarily imposed conditions of military requirements. Although much of the scientific work of the war has been done individually, probably by far the greater part has been by collective efforts of groups of workers usually under the guidance of some responsible committee or executive. Although this is no new phenomenon in scientific research, yet this cooperative method of attacking difficult problems has been, under the stress of war, developed to an hitherto unheard-of degree. It is probable that the naturally individualistic traits of scientific men will tend to cause a lessening of this type of common endeavor; although in the distribution of investigation, between groups or individuals, there will probably be a greater number of groups than before the war, the habit of working together having been fostered, and its advantages appreciated in certain cases. For scientific research carried out in the interest of industry, this group method will very likely be greatly developed.

STANDARDIZATION

One of the fundamental factors of the greatest economic importance, which the exigencies of the war have brought repeatedly to the fore both in battle and in workshop, is what one might almost call the crusade of standardization. This has taken on innumerable aspects and has constantly been recurring in conservation programs, economic production, and in the elimination of waste, time, materials, and men. The savings that may be accomplished by the scientific application of what we may call the principles of standardization in production, manufacture, and distribution of many, if not most, of the more usual commodities of commerce and industry is so great that I believe that it is not an exaggeration to say that by this means alone our national debt could soon be paid off, both interest and principal. An indication of what can be done along this line has been ably demonstrated in our own country by The War Industries Board and in particular its Conservation Division working in cooperation with the various industries.

This cooperation between Government and industry has been made most effective by the enforced revival of the guild organization in industry. The fact that an industry has been represented successfully as a whole during the war by an elected committee in treating with the Government and among themselves on matters of common interest, is charged with great possibilities for like action along voluntary lines during peace times. Although of course many of the questions thus treated may be considered as outside the realms of science, nevertheless the scientific man cannot be separated from this development, which, it is most urgently desired, may be continued, although along less arbitrary lines than were necessary in time of war.

SPECIFICATIONS

A closely related matter is that of preparing satisfactory specifications for materials and manufactured articles. Washington might almost have been called a specification factory during the past eighteen months. This is economically one of the most important of subjects and too great emphasis cannot be given to the desirability, not merely for materials of military interest but for all uses, of being able to define adequately and sufficiently—not too loosely nor yet too rigorously—the materials and articles that form the basis for practically all purchases. There have been, and still are in many fields, great confusion, uncertainty, and differences of opinion as to facts, and most of this is, in the last analysis, a result of ignorance of the scientific data regarding properties and materials on which the specifications are based. The nation has undoubtedly suffered untold losses on account of this ignorance, and endeavors should be made on a sufficiently comprehensive scale to eliminate as much as possible the waste arising from this cause.

Innumerable instances could be cited of the harmful and costly effects of too rigid specifications and of course we all know some of the dangers of too loosely drawn specifications. I will cite two of the former in my own field of metallurgy. A foreign government had a limitation, dating some thirty years back, of 0.05 per cent copper in a certain grade of munition steel

being made here. All the steel made from certain ores in this country necessarily carried four or five times the stipulated copper. Although at first insisting on the rejection of the steel, the government in question finally accepted it after overwhelming evidence was submitted showing that ten times the amount of copper was not only not detrimental but also of actual advantage in this steel. This single contract involved several millions of dollars; the total cost of all the experimental work ever done the world over on the effect of copper on steel would be at most a few thousands.

The second illustration is given by another government which desired to purchase steel here for aircraft parts with a phosphorus and sulphur content together of less than 0.03 per cent. They could buy no steel, and if they had been able to place an order it would have been at an exorbitant price. The fact that all the other allied countries were using a much less rigid specification with safety finally convinced them that theirs was too severe. Incidentally this latter case shows the evident advantages of interchange of ideas and experience in such matters.

Not a little of the delays in production of many materials for war purposes was due to the multiplicity of specifications insisted upon by the various independent purchasing departments of the Government. Some progress is being made toward unity in standardization and specifications in the War Department and it is highly desirable that there be constituted a central body with authority for all departments. A single board, for example, to frame metal specifications for all would make for economy and efficiency.

That the technical public is now ready for such simplification and uniformity is evident by the recent creation, somewhat on the British model, of the Engineering Standards Committee. The Germans are also said to be forming a similar organization and the French and Italian governments have organized standards committees. It is to be hoped that this is one of the after-war activities to be pushed. It is not too much to say we have entered an era of standardization. It is not necessary before a

group of scientific men, however it may be elsewhere, to state that standardization necessarily involves research, often very elaborate and costly.

INDUSTRIAL RESEARCH

The relation of science to industry has been a fruitful subject for discussion in recent years both here and abroad and nowhere has the question of industrial research, as it is often called, been cultivated more intensively and made more progress as a direct result of the war than in Great Britain; and it may be of interest to mention briefly some of the steps in the progress.

Following the economic congress of the Allied Nations at Paris, there was formed in July, 1916, a committee, presided over by Lord Burleigh, on commercial and industrial policy after the war, and the reports emanating from this body and its auxiliaries cover the whole field of the economic aspects—industrial, commercial, technical, and scientific—of the after-war period, and lay particular emphasis, for example, on the protection and development of "key" or "pivotal" industries, most of them requiring the highest grade of scientific and technical skill for their maintenance and advancement, such as synthetic drugs, optical glass, chemical glassware and porcelain, dyestuffs, magnetos, high explosives, etc.

It is of interest to note in passing that the questions of decimal coinage and the compulsory use of the metric system of weights and measures were also considered and their adoption not advised. The arguments advanced for this conservative stand, if valid, are of a nature that would seem to make it difficult ever to make the metric system universal. A transition period like the present has precedent for the establishment of such a simplification of units and standards; for the metric system originated during the French Revolution and the International Bureau was founded at the time of the war of 1870.

There has since been established in England a Ministry of Reconstruction to deal with the numerous problems the transition period presents. A Department of Scientific and Industrial Research with a Parliamentary Secretary has also been created

and has been active for nearly two years: (1) It has been encouraging firms in well-established industries to undertake co-operative study of the scientific problems affecting their processes and raw materials, and has at its disposal a sum of one million pounds for grants on the basis of an equal subscription from industry; (2) the Department has further prepared to undertake at the public cost investigations of general interest; (3) the importance to industries of the establishment of standards on a scientific basis is recognized and the financial control of the National Physical Laboratory has been taken over, with provisions for pensioning the staff; (4) efforts are being made to increase the numbers of trained research workers, which had reached a dangerously low ebb in 1915 as recognized by Lord Burleigh's committee, who found but forty qualified, unattached persons available for research in the United Kingdom.

Very substantial results have already been achieved in these several fields and hardly a copy of *Nature* can now appear which does not record some new grant, technical committee, industrial research association, or other advance in the interdependence of science and industry under governmental supervision. It is also especially significant to note that some of the industries are also standing on their own feet and establishing their own research laboratories along cooperative lines.

There is also the recently founded British Science Guild with a distinguished membership which maintains lectureships and does much to foster the dissemination of the aims of research among the public.

This spirit of organized research has been contagious throughout the British Empire and there are being established similar associations, institutes, and laboratories in Canada, Australia, South Africa, and elsewhere.

Rather curiously in the democratic British communities, it is the Government that appears to be taking the lead in the stimulation of scientific research, particularly in its relation to industry. It is probable that the reasons for governmental initiative are in part a result of the abnormal conditions of the nation at war

during which time individual efforts are much more difficult of effective expression—the community in the time of danger is thinking and acting as a unit under military stress, and military methods predominate. As normal times return we may expect the state to relax its vigilance and the individual person, society, or industry to reassert to a greater degree their qualities of initiative and independence. It is not improbable, however, that there is a genuine conscious effort for the more generous support of research by the British public as a national asset, which support will be maintained in peace times on a much more extensive scale than in pre-war times.

UNION OF SCIENTIFIC WORKERS

Another incident significant of the trend of the times is the formation in October last of the British National Union for Scientific Workers with five hundred members whose main objects, most worthy of repeating here, are: (1) to advance the interest of science as an essential element of the national life; (2) to regulate the conditions of employment of persons of adequate scientific training and knowledge; (3) to secure in the interests of national efficiency that all scientific and technical departments in the public service, and all industrial posts involving scientific knowledge, shall be under the direct control of persons having adequate scientific training and knowledge.

The question that every scientific man in America naturally and perhaps unconsciously asks himself on hearing of such an organization is, of course, why not form such a union here? Indeed, the matter has been discussed in some centers and it would probably not be difficult to organize in the United States a similar union of scientific workers. Bodies somewhat similar already exist among various educational and professional groups. It should be borne in mind, however, in considering this matter that in addition to the general objects stated above, the scientific workers of England were almost compelled to organize in order to have representation on the so-called Whitley Industrial Councils, having to do with matters affecting labor and management relations in industry and one of the creations of the reconstruction program.

Forming what is perhaps the natural corollary to the foregoing, there has been some serious discussion in Britain of the desirability of having representatives of science as such in Parliament; certain of the universities have had representation for a long time but it is doubtful if the matter of representatives of science is pushed seriously. If science, why not literature, the arts, and so on?

While we are considering the question of the scientific man himself, there is one phase of his relation to science and to industry that I cannot pass by, which will need perhaps even more serious consideration in this transition period than it has had in the past. I refer to the bidding for his services by technical industries. A man who leaves the university or professional school and enters the research department of an industrial concern is not the man I mean. Is not the case different for a man who has chosen his career of scientific investigation in a university or other scientific institution independent of or under state control? This man, if taken from his environment by offers of financial gain, goes to enrich most certainly some special interest with his science and is still a valuable member of the community; but generally speaking, is it not of advantage to the community to keep that man contented in his, what I am tempted to call, more natural environment? Natural, for he chose it and adapted himself to it. When the staff of an institution of the character of the Geophysical Laboratory is in danger of being absorbed by industry, does not the matter become of serious concern? Should not the industries rather be encouraged to take their scientific men when they are young and not break up going scientific concerns? No doubt a certain amount of interchange in scientific personnel is to be encouraged but it should be interchange and not bleeding practiced by industry. Providing an adequate supply of scientifically trained men for the needs of industry, and defining the proper relations between industrial management and scientific centers, are questions meriting the most serious concern of the community. Our supply of scientifically and technically trained men is all

too meager and if, as many expect, there is now to be a period of expansion in the foreign trade of the United States involving possibly the establishment abroad of numerous branches of highly technical industries, the demand for such men will become more urgent than ever, particularly in the case of men of scientific training with engineering experience.

EDUCATION OF SCIENTIFIC WORKERS

This brings us to the question of the education of scientific men, which subject it is possible to mention but briefly. Here again the interruption, disorganization, and readjustment of educational training in America have been insignificant as compared with the disturbances in education brought about by the necessities of war of the European countries, but even in this country experiments with intensive training and shortened courses have been tried on a large scale but, it must be borne in mind, for a limited period only. Our educational institutions will undoubtedly be able to preserve some of the beneficial characteristics brought out by such speeding up but for the most part there probably will be little effect on the kind of training our scientific men will get.

It would appear to be highly desirable that as large a proportion as heretofore of our scientific men pass a portion of their preparative period abroad amid cultural surroundings different from those in which they grew up. As a beginning it is to be hoped that many of our young men now in France will be given the opportunity to take advantage of the generous offer of the French Government for instruction in the schools and universities of France. This if carried out on a considerable scale, will have far-reaching effects, the benefits of which can hardly be overestimated. It is also to be hoped our universities will not only encourage the coming of foreigners more than heretofore but also render easier the migration of American students from one American institution to another. The establishment in Washington of schools framed on lines similar to the "Ecole des Hautes Etudes" and the "College de France," which are devoted exclusively to research would go far toward making more gener-

ally available the research facilities and scientific men of the capital.

During the war the scientific men of the country have been thrown into close association with each other, perhaps even closer in many instances than in pre-war times in spite of the decrease of attendance at scientific meetings and in the number of such meetings; in addition, there have been developed, as never before, acquaintance and cooperation of the men of science of this and the allied countries; and not only the men of one science have been thrown together but representatives of what we ordinarily consider very diverse sciences have been brought into close personal and professional contact. All this makes for the unity of science and the broadening of scientific men. It would seem desirable to make an effort to perpetuate this habit of association of scientific men from different countries. You will recall that in 1914 there were projected several international congresses in science and engineering. Would it not be well, as soon as circumstances permit, at least to revive these projected congresses with such limitations as comply with the conclusions reached recently in London by representatives of the National Academies of the Inter-Allied Nations?

SCIENTIFIC PUBLICATIONS

A very important matter, that has been held generally in abeyance by the war, which will soon again require the serious attention of scientific gatherings, is that of the policies regarding scientific publications. Very definite proposals have been discussed recently in England looking particularly to the avoidance of duplication, confusion, and other anomalies in scientific literature and to its more effective distribution. This question again is a variant of the standardization problem and is further complicated by interests or prejudices, both national and professional, of numerous societies representing often, if not competing, yet overlapping fields of science. For any particular branch of science, there are also the international aspects to be considered including the question of language; and it is within the bounds of possibility, for example, that there will occur a

revival of the more concerted efforts for the use of an auxiliary international language such as Esperanto, or, if you will, some standardized international form of expression in science.

If I have dwelt with less emphasis on some of the recent, strictly American tendencies of scientific development, I trust it fair to assume you are acquainted with most of them. The great work of the National Research Council is certainly familiar to us all and it is good news to hear that plans are being developed toward reorganizing the Council to meet the conditions of the reconstruction period. There is great need in the United States, with our relative geographical isolation and great distances between many scientific centers, for an active scientific body devoted to the initiation, stimulation, and correlation of scientific research.

Furthermore, by emphasizing the recent British developments in the relations of state, industry, and science, I by no means desire to imply that we have not been active in America. These matters are being freely discussed here and many plans are being formulated, and some are in operation, for cooperative research in various branches of science particularly as applied to industry. The weekly and monthly scientific press are full of them. It is to be noted that in contrast with the British experience, in America less expectation is being placed on governmental aid to new research projects; an exception to this is, of course, the Smith-Howard bill now before Congress for promoting engineering research in the several states.

CONCLUSIONS

In America, individual initiative in the past has on the whole been more potent than the state in providing the funds for maintaining research. In the prosecution of the war now drawing to a close, however, the Federal Government has spent huge sums on projects requiring scientific investigation and development, and, in order to carry out the scientific projects of military urgency, has mobilized the scientific men of the country. Is it well during the after-war period to demobilize completely this army of scientific men? No one would yet think of having

no organized military force in peace time, and there is in every well-organized state always at least a skeleton army with all branches represented, including a competent staff, arsenals, depots, surplus munitions, and supplies.

The great scientific bureaus of the Government are organized for the problems of peace and, although they can give a good account of themselves under war conditions, yet would it not be well, at least until the millennium is more clearly in sight, to retain more than a nucleus of an organization of scientific men in the service of the state and especially in the military and naval establishments? We can all name branch after branch of each of these services which before the war contained almost no scientific personnel but to which have been added during the war scores and hundreds of scientific men; and in some cases it was no easy matter to gather and coordinate this personnel.

What therefore appears to me as one of the very important problems of the transition period, namely the proper balancing and distribution of the scientific forces of the country as between the military and civilian activities of the state on the one hand, and the industrial and academic activities of the country on the other, is even now undergoing the process of being solved. The readjustment will go on largely unperceived at the moment, and the changes will be accompanied by the usual quiet but significant struggles. The more rapidly the world settles down to more stable conditions, the more promptly will we reach this dynamic equilibrium of the distribution of scientific men and the balancing of competing fields in scientific research.

GEOLOGY.—*Lower Cretaceous age of the limestones underlying Florida.*[1] JOSEPH A. CUSHMAN, Sharon, Massachusetts. (Communicated by T. W. Vaughan.)

A study of the Foraminifera of well borings from a number of the deeper wells of Florida has proved of more value than was at first expected. Some of these wells reach depths not heretofore penetrated in this area. The wells giving the most important results and their depths are as follows:

[1] Published by permission of the State Geologist of Florida.

Near Burns, Wakulla County; 2,153 feet.
Jacksonville, Duval County; 980 feet.
St. Augustine, St. Johns County; 1,440 feet.
Anthony, Marion County; samples from 50–500 feet.
Eustis, Lake County; samples from 100–180 feet.
Bushnell, Sumter County; samples from 380–3,080 feet.
Apopka, Orange County; samples from 50–390 feet.
Sanford, Seminole County; samples from 95–113 feet.
Cocoa, Brevard County; a sample from 190 feet.
Tiger Bay, Polk County; 770 feet.
Okeechobee, Okeechobee County; samples to 500 feet.
Fort Myers, Lee County; 950 feet.
Marathon, Key Vaca, Monroe County; 2,300 feet.

The examination showed many Foraminifera, among which were two species of the genus *Orbitolina* occurring at different levels. One of these, a small conical species, is encountered at much higher levels than the other which is a large, low, somewhat concave species. The first of these is very close to, or identical with, a species of *Orbitolina* known from the Quitman Mountains of Western Texas, where it characterizes a horizon of the Fredericksburg group of the Lower Cretaceous. A species seemingly identical is found in the Lower Cretaceous of the Province of Navarra in northern Spain. Other species of different groups, echinoderms, etc., are identical in Spain and northern Mexico in the Lower Cretaceous.

Below the Fredericksburg in the Quitman Mountains, in the same section, in the Trinity group of the Lower Cretaceous are horizons marked by great numbers of *Orbitolina texana* which is seemingly identical with the larger species of the Florida well borings and found only at some depth below the conical species. In the borings accompanying these species are others that are close to Lower Cretaceous species of Europe.

The limestone characterized by these species of *Orbitolina* seem to underlie practically the whole of the peninsula of Florida, being found in the wells at the north near Burns, Jacksonville, and St. Augustine, in the well at the south on Key Vaca, and in the central region at Anthony, Eustis, Bushnell, Apopka, and Tiger Bay.

Assuming the altitude above sea level at Apopka as 150 feet,

the Lower Cretaceous stands 35 feet above present sea level, for the conical *Orbitolina* appears in the well borings 115 feet below the surface. From similar data it appears to be 33 feet below sea level at Anthony and less than 100 feet below sea level at Eustis.

At other localities, it is 400 feet below sea level at St. Augustine, 820–845 feet at Jacksonville, 500 feet at Tiger Bay, and 1,248 feet at Marathon. Assuming an even rate of slope and that the conical *Orbitolina* is confined to a single horizon, this gives a dip southward from Apopka to Tiger Bay of about 9 feet to the mile and from Apopka northeastward to St. Augustine of about 6 feet to the mile. A low anticline is thus indicated with its center somewhere in the general region of Apopka.

On the upper surface of this Lower Cretaceous limestone the upper Eocene is represented by the Ocala limestone and in part at least by the Claiborne. The borings indicate that this contact is unconformable, because there is no Upper Cretaceous present in any of the well samples that were examined. This may be due to deposition and subsequent erosion or to the area being a land mass at this time. As the Washita, or upper group of the Lower Cretaceous, is unrepresented so far as can be seen, this group, if deposited, may have been eroded during Upper Cretaceous time while the whole area was elevated to a slight degree, the elevation having taken place, as in other regions, at the end of Lower Cretaceous time. The structure indicates this possibility rather than that the whole series was deposited and subsequently was entirely removed by erosion. It seems then that the area must have been a land mass during Upper Cretaceous and early Eocene time.

The Ocala and Claiborne are not represented, as far as the samples show, at Apopka and this area may have been an island during the deposition of the Ocala.

Where the typical Ocala is developed it seems to be only about 40 feet thick instead of the much greater thickness usually assigned to it. The fossils of the Ocala are brought up from lower levels but are evidently specimens that have dropped down from higher levels during the drilling. A bed of peculiar

Nummulites characterizing the Claiborne occurs just below the Ocala and makes an excellent criterion for delimiting that formation. The Ocala also dips to the northeastward and to the south from the Apopka region.

From the present occurrence of the Ocala above sea level in west central Florida and its occurrence in the Tiger Bay and St. Augustine wells at 360 and 224 feet, respectively, below the surface, a dip somewhat like that of the Lower Cretaceous is indicated.

The general conclusion from the evidence of the Foraminifera is that the whole of the Florida peninsula and probably a part of north Florida as well, as indicated from the data near Burns, are underlain by rocks of Lower Cretaceous and perhaps older age and that on the Lower Cretaceous the upper Eocene beds were deposited. The area was probably uplifted at the end of the Lower Cretaceous and remained a land mass during Upper Cretaceous and early Eocene time, after which it was again depressed and except in the region of Apopka was under water during the deposition of the Ocala limestone in late Eocene time.

EPIDEMIOLOGY.—*A contribution to quantitative epidemiology.* ALFRED J. LOTKA, New York City.

In his recent paper on Pathometry[1] Sir Ronald Ross develops, for a certain class of cases, the equation

$$F_{t,o} = A/P \int_o^\infty c\, F_{t,s}\, ds. \qquad (1)$$

In this equation $F_{t,s}\, ds$ denotes the number of cases which at time t have been affected for a length of time comprised within the limits of s and $s + ds$; $F_{t,o}$ is accordingly the rate at which new cases are developed at time t. The total population is P, the unaffected population A, while c is the coefficient of infectivity.

A solution is given by Sir Ronald Ross, among other things, for the special case that the coefficient of infectivity c is inde-

[1] Proc. Roy. Soc. 93: 235.

pendent of the "duration" (age dated from inception) of the case, and that $F_{t,s}$ is constant, namely

$$F_{t,s} = F_{t,o} \tag{2}$$

over the range defined by

$$q_1 < s < q_2 \tag{3}$$

while

$$F_{t,s} = 0 \tag{4}$$

outside of this range.

A solution can still be obtained, as indicated below, if we abandon these restrictions,[2] retaining only the following assumptions:

1. Immigration and emigration are negligible.

2. The affected population is always a small fraction of the total and, the total population being given as constant, the unaffected population also may therefore be considered as practically constant.[3]

3. The coefficient of infectivity c, though a function of the duration s, is independent of t. This is equivalent to saying that the infectivity of the disease varies in each affected person according to the "age" (duration) of the case, but is the same function of this age from case to case, at all times.

Equation (1) is then of the form

$$F_{t,o} = K \int_{q_1}^{q_2} c\,(s)\, F_{t,s}\, ds. \tag{5}$$

[2] We shall, however, retain the condition expressed in Equation (4). This is virtually no restriction at all since q_1 and q_2 in (3) may be given any values from o to ∞, and in practice the duration of the disease is always limited to finite time. At most the condition (4) might be construed as excluding infection by nonaffected carriers.

[3] In the notation of Sir Ronald Ross's paper we have, in fact, in this case $\frac{A}{P} = \frac{P-Z}{P} = 1$ since Z, the affected population, is small as compared with P, the total population. The coefficient K which occurs in (5) and subsequent equations is thus practically unity.

The case is here analogous to that of certain chemical reactions in which one of the reacting substances is present in large excess, as for instance water, when used as a solvent for the reacting substances in dilute solution, and when itself consumed or formed in the process. The concentration of the water in such cases may be regarded as practically constant.

It will be convenient to adopt a somewhat different notation to designate $F_{t,s}$ the "survivors" at time t, "of duration s," out of the original batch $F_{t,o}$ of new cases.

If we denote by $F(t)$ the new cases per unit of time at time t, and consequently by $F(t-s)$ the new cases per unit of time at time $(t-s)$, then let $F(t-s)\ p(s)$ denote the survivors at time t of the new cases per unit of time which originated at time $(t-s)$. Evidently the relation between this notation and that in the original paper referred to above is

$$F_{t,s} = F(t-s)\ p(s). \tag{6}$$

In this notation (5) becomes

$$F(t) = K\int_{q_1}^{q_2} F(t-s)\ p(s)\ c(s)\ ds \tag{7}$$

which, in view of (4), may indifferently be written

$$F(t) = K\int_{o}^{q_2} F(t-s)\ p(s)\ c(s)\ ds. \tag{8}$$

The integral equation (8) is of the type dealt with by Hertz.[4] To solve it we must know the value of $F(t)$ from $t=0$ to $t=q_2$, or what is the same thing, the number of cases at every "age" (duration) between 0 and q_2 at time $t=0$. We may leave out of account the number of cases of "age" (duration) above q_2 at time q_2, since they have ceased to be infective.

We have then by Hertz

$$F(t) = \sum_{h=1}^{h=\infty} \frac{e^{u_h t}\int_o^{q_2}\left\{F(s) - K\int_o^s p(s_1)\,c(s_1)\,F(s\,s_1)\,d-s_1\right\}e^{-u_h s}\,ds}{K\int_o^{q_2} s\ p(s)\ c(s)\ e^{-u_h s}\ ds}$$

Where $u_1, u_2 \ldots$ are the roots of the equation for u

$$1 = K\int_o^{q_2} p(s)\ c(s)\ e^{-u s}\ ds. \tag{10}$$

[4] Math. Ann. **65**: 86. At the same time, it will also no longer be warranted to make the assumption (implied in a constant population) that the death rate is not appreciably affected by the progress of the disease (unless indeed the disease is never fatal). Moreover, if a large proportion of the population has become affected, the unaffected portion of the population will in practice be inherently different in character from the total population. It will contain a larger proportion of persons of low "susceptibility." So long as the number of persons affected forms but a small fraction of the total population, we may neglect this "selective" effect, as has been done above. But with a large "affected" proportion of the total population this neglect is no longer justified.

From the nature of the case q_2, $p(s)$, and $c(s)$ are never negative. It follows that (10) has one and only one real root U, which is $\gtreqless 0$ according as

$$K \int_0^\infty p(s)\, c(s)\, ds \gtreqless 1 . \qquad (11)$$

It can easily be shown that any other root must have its real part less than U.

It follows that for large values of t the term with the real root U outweighs all other terms in (9), and $F(t)$ approaches the value

$$F(t) = F(0)\, e^{Ut} . \qquad (12)$$

Furthermore,

$$F(t - s) = F(0)\, e^{U(t-s)} \qquad (13)$$

and

$$F_{t,s} = F(t - s)\, p(s) = F(0)\, e^{U(t-s)}\, p(s) \qquad (14)$$

The function $F_{t,s}$ is thus determined.

For $Z(t)$, the total number of cases existing at time t, we have by Equation 86 of Sir Ronald Ross

$$Z(t) = \int_0^\infty F(t - s)\, p(s)\, ds \qquad (15)$$

$$= F(t) \int_0^\infty e^{-Us}\, p(s)\, ds \qquad (16)$$

$$= C\, F(t) \qquad (C = \text{const.}) \qquad (17)$$

since we are assuming that $p(s)$ is independent of t; and hence by (12)

$$Z(t) = C\, F(0)\, e^{Ut} \qquad (18)$$

$$= Z(0)\, e^{Ut} \qquad (19)$$

that is to say, the affected population increases in geometric progression with the time, at the same proportional rate as do the new cases per unit of time.

In practice, if this state of affairs persists, a time must be reached when, with a constant total population, the affected population can no longer be regarded as a small fraction of the total, and when, therefore, the solution here given no longer applies.[5]

One point deserves special notice. It will be observed that since U is determined by Equation, (10), it is wholly independent

[5] See footnote 4.

of the subsequent fate of the affected persons after they pass beyond the period $q_1\ q_2$ of infectivity, or of their condition before they enter it, provided only that they enter it with a given value of p (q_1). This may appear at first sight somewhat surprising, but on reflection is found to be in accord with reason.

The case discussed above is strictly analogous to the "Problem in Age-Distribution" which has been treated by Prof. F. R. Sharpe and the writer elsewhere.[6] The development given above is what the present author had in mind when he wrote, in a previous publication:[7]

> Brief reflection shows that we can apply to this case (endemic disease) a mathematical treatment precisely analogous to that of the growth of a population; for we may think of the diseased portion of the population as a separate aggregate, into which new individuals are recruited by fresh infections, just as new individuals enter an ordinary population by procreation. On the other hand, members are continually eliminated from the aggregate, first by deaths, secondly by recoveries. On the basis of these considerations formulae can without difficulty be established between the factors enumerated above. Such general formulae, however, involve certain functions which are unknown, and the determination of which by statistical methods would at best present great difficulties.

In conclusion it may not be out of place to remark that, aside from mathematical similarity, what places the two cases—growth of a population and spread of a disease—in the same class, is the physical circumstance that both are cases of autocatalytic or autocatakinetic growth. The rate of growth at any instant increases with the size of the existing nucleus or focus, other things equal.

[6] See also SHARPE and LOTKA. Phil. Mag., Apr. 1911, p. 436.

[7] Nature, Feb. 8, 1912, p. 497.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors The abstracts should conform in length and general style to those appearing in this issue.

PHYSICAL CHEMISTRY.—*The color of inorganic compounds.* F. RUSSELL V. BICHOWSKY. Journ. Amer. Chem. Soc. **40**: 500–508. March, 1918.

It is shown that every valence state of an element can be associated by means of purely experimental evidence with a definite "atom color." There is a marked relation between atom color thus determined and valence and valence variability. The atom color of every element in its normal valence state, that is, in the valence state which corresponds to its place in the periodic system, is zero (all nonvariant-valence atoms have their normal valence). The atom color of an element, in valence states where the valence is decreased or increased by an odd number from the normal valence, lies further in the blue than the atom color of the same element in any other valence state. The atom color of an element in a state whose valence is removed by an even number from normal will be zero if compounds of the element do not exist in which the valence of the element is removed by an odd number from normal; otherwise the atom color will lie further in the yellow than the atom color of the same element in a state of valence removed by an odd number from normal. Compounds between nonvariant-valence elements will be colorless. Compounds between a nonvariant-valence element and a variant-valence element will have the same color as the "atom" of variant-valence element. Compounds between other elements will have colors more to the blue than the sum of their atom colors. All these regularities can be deduced from a variation of Lewis's theory of atom structure. The almost perfect accord between the deduction and the facts indicates very strongly that Lewis's fundamental hypotheses are correct. F. R. B.

INORGANIC CHEMISTRY.—*The equilibrium between carbon monoxide, carbon dioxide, sulfur dioxide, and free sulfur.* JOHN B. FERGUSON. Journ. Amer. Chem. Soc. 40: 1626–1644. November, 1918.

This paper contains an extended account of the investigation of the reaction $CO + {}^1/_2SO_2 \rightleftarrows CO_2 + {}^1/_4S_2$, a partial summary of which appeared last year. The study was undertaken primarily as a part of a comprehensive study of certain gas reactions and their rôle in volcanic activity, and this particular reaction was selected because it afforded a direct means of determining the free energy or thermodynamical potential of sulfur dioxide, one of the most important of the volcanic gases.

The composition of the equilibrium gas mixtures obtained, with the corresponding initial gas mixtures, both calculated and actual, and the resulting equilibrium constants, are given in tabular form and the thermodynamical calculations based thereon given in detail. The latter give an average mean value of 3.99 for the thermodynamical constant I and − 22510 calories for the change in free energy for the reaction under standard conditions. For the reaction $S_R + O_2 \rightleftarrows SO_2$ under similar conditions, the value for the change of free energy is − 69761.

R. B. SOSMAN.

ENTOMOLOGY.—*Memoirs on the Coleoptera VIII.* THOMAS L. CASEY. New Era Printing Company, Lancaster, Pa. November 12, 1918.

In this volume the author reviews several large subfamilies of the Carabidae or ground beetles. A very large number of new species and subspecies are described, especially in some of the groups of the Bembidiinae and in the *Celia* and *Amara* of the Amarinae. A résumé of the American genera and subgenera of the Pterostichinae is given in some detail. There can scarcely be a doubt that all the forms enumerated have at least some taxonomic standing, although the true interrelationship of the various units is a problem that cannot be solved except in many years of careful study.

There are two passably definite methods in the investigation of natural groups in the Insecta, so far as the delimitation of species is concerned. One of these methods, which is more especially developed among the German investigators, constantly bears in view the overlooking of differences, in order to reduce specific forms to the smallest

possible number. The other, which might be regarded as more essentially the French system, carefully records differences, whether of structure or facies, and endeavors to formulate a taxonomic scheme in accordance therewith. One system is based more especially upon resemblances, the other upon differences. Either system when carried to an extreme must involve mistakes, though knowledge as a whole is more likely to be advanced by the second than by the first of these systems. The author of the present volume inclines to the French system, which apparently is also preferred by most of the English investigators. T. L. C.

APPARATUS.—*Temperature uniformity in an electric furnace.* JOHN B. FERGUSON. Phys. Rev. 12: 81–94. July, 1918.

The problem of temperature uniformity in an electric furnace is intimately connected with almost all investigations carried on at high temperatures. For this reason it has generally been considered as a part of a larger problem and has been solved to the extent demanded by the requirements of the work at hand. In this paper the writer presents a more general discussion of the subject, together with many results obtained by him in his various investigations bearing directly thereon. The production of temperature uniformity in an electrically heated air column may best be done by means of three independent heaters and end plugs. R. B. S.

APPARATUS.—*Thermal leakage and calorimeter design.* WALTER P. WHITE. Journ. Amer. Chem. Soc. 40: 379–393. February, 1918.

The interchange of heat between a calorimeter and its environment (thermal leakage) is practically proportional to their temperature difference, except for the effect of evaporation and for that of convection, which is, for ordinary calorimetric conditions, more nearly proportional to the square of that difference. If evaporation is suppressed the advantages of a constant thermal leakage factor are obtained by preventing convection. Recent investigations upon convection show how this may most advantageously be done. In adiabatic work there is little fear of convection, hence either very large temperature intervals or very large air gaps can be profitably employed. Incidentally, it is pointed out that the ordinary rule, that thermometric lag causes no error where only one thermometer is used, deserves careful interpretation, or else restatement, in the case of some thermochemical determinations. R. B. S.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

WASHINGTON ACADEMY OF SCIENCES

At the meeting of the Board of Managers on January 10, 1919, it was voted to turn over the accumulated exchanges and miscellaneous publications owned by the ACADEMY to the Librarian of the Smithsonian Institution, with the request that he first complete the files of the Institution where possible, and then distribute the remainder in whatever manner will make the publications most useful to scientific libraries.

The following persons have become members of the ACADEMY since the last issue of the JOURNAL:

Mrs. AGNES CHASE, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

Mr. JOHN BRIGHT FERGUSON, Geophysical Laboratory of the Carnegie Institution of Washington, Washington, D. C.

Mr. MORRIS HACKER, District Building, Washington, D. C. (Nominated as Vice-President by the Washington Society of Engineers.)

Dr. EUGEN W. POSNJAK, Geophysical Laboratory of the Carnegie Institution of Washington, Washington, D. C.

Mr. SIEVERT ALLEN ROHWER, Bureau of Entomology, U. S. Department of Agriculture, Washington, D. C.

ROBERT B. SOSMAN, *Corresponding Secretary*.

THE ENTOMOLOGICAL SOCIETY OF WASHINGTON

The 318th regular meeting of the Society was held in the hall of the Carnegie Institution, January 8, 1919. There were present 32 members and 5 visitors.

The President read the following list of members of the Society who have been in the military service: Captains D. L. VAN DINE, A. H. JENNINGS, J. D. HOOD, E. H. GIBSON, and G. F. WHITE; Lieutenants W. H. WHITE, L. H. DUNN, and E. W. SCOTT; Sergeant R. C. SHANNON, and Privates WM. MIDDLETON and C. A. WEIGEL, while Dr. O. H. BASSECHES was in training camp at the signing of the armistice. Of these Captain A. R. JENNINGS has died in the service. The President appointed Dr. W. D. PIERCE, Mr. AUGUST BUSCK, and Dr. A. G. BOVING as a committee to draw up a memorial and prepare a bibliography of Captain JENNINGS.

The regular program was as follows:

E. R. Sasscer: *Hydrocyanic-acid gas and its use in the control of insects.* (Presidential address.) This paper dealt with the history of the use of hydrocyanic-acid gas in the control of insects. Reference was made to its discovery in 1872 by Scheele and its early use as an insecticide in California in 1886 by D. W. Coquillett. Brief reference was made to the occurrence of hydrocyanic acid in nature, indicating that in addition to its occurrence in the secretion of certain myriapods, it is also found in the seed, foliage, or bark of certain plants, thirty-odd plants being listed which contain the acid in nature.

After discussion of the preparation of hydrocyanic-acid gas as used against insects, a brief history of its use against the following was given: Citrous Insects, Greenhouse Insects, Mill and Stored Product Insects, Nursery and Deciduous Fruit Insects, Household Insects and Sanitation, and Soil Insects.

Brief mention was made of the effect of this gas on the germination of seed. Also the effect of the gas on insects and man was given consideration.

The reading of the address was followed by lantern slides showing the development of the apparatus used in the fumigation of citrous trees and the vacuum process of fumigating nursery stock and bale cotton.

The address called forth a lively discussion. Mr. Schwarz stated that he had first used cyanide of potassium in his killing bottles about 1868, and that he had seen it used as an insecticide for the protection of crops as early as 1879. This was in a small vineyard in Texas, the owner surrounding his vineyard with a belt of cyanide of potassium solution to protect it from the ravages of leaf-cutting ants. Immense numbers of the ants were killed in attempting to cross the poisoned ground.

Dr. Quaintance recalled the remarkable activity in the development of insecticide work at about the time hydrocyanic-acid gas was first used. Mr. Hutchison spoke of the experimentation with war gases as insecticides and of the great success attending the use of some of them.

As a possible explanation of the difficulty of killing certain insect larvae, Dr. Böving explained the mechanism of the closing apparatus in the tracheae.

Notes and exhibition of specimens: Mr. Schwarz commented on the fact that an Australian lady-bird beetle which has stood in the literature as *Vedalia koebelei* Blackburn has never been described by Blackburn, but the preparatory stages were described by Coquillett in such manner as to fix the species, which must, therefore, be known as *Vedalia koebelei* Coquillett. Dr. Quaintance mentioned the case of the recently described Californian apple *Coleophora*, which through delay in the publication of its description by Heinrich, its real author, and the description of it in an economic paper by W. D. Volcke, must be known as *Coleophora volckei* Volcke, placing Mr. Volcke in the position of naming a species for himself. Other examples of this were cited by Dr. Howard, Mr. Schwarz, and Mr. Caudell.

Mr. Hutchison exhibited photographs showing method of rearing body lice for experimental purposes.

R. A. Cushman, *Recording Secretary.*

SCIENTIFIC NOTES AND NEWS

Captain HOWARD E. AMES, Medical Director, U. S. N., Retired, died on December 27, 1918. Dr. Ames had been an officer in the Navy since 1875, and had been on the retired list since 1912. He served as medical officer on board the *Bear*, which rescued General Greely and his party in the Arctic regions. He was a member of the Biological Society.

Mr. ANDREW BRAID, hydrographic and geodetic engineer of the U. S. Coast and Geodetic Survey, and chairman of the U. S. Geographic Board, died on January 3, 1919, in his seventy-third year. He was a native of Scotland, and had been in the service of the U. S. Government since 1869. He was chief of the instrument division for several years, and was in charge of the standard weights and measures of the United States during the years just preceding the establishment of the Bureau of Standards.

Dr. KELVIN BURNS of the Division of Optics, Bureau of Standards, is absent on an extended trip abroad in connection with his scientific work.

Col. G. A. BURRELL, of the Chemical Warfare Service, returned to private chemical engineering work at Pittsburgh in January. He was called to Washington by the Bureau of Mines early in the war, to take charge of the research organization that later became the American University Experiment Station of the Chemical Warfare Service.

Mr. ALONZO HOWARD CLARK, curator of the division of history of the National Museum, and editor of publications at the Smithsonian Institution, died on December 31, 1918, in his sixty-ninth year. Mr. Clark was born at Boston, Massachusetts, April 13, 1850. He had been with the Smithsonian Institution since 1881. He was the author of several publications on the fishery industries of the United States, and was a frequent contributor to historical and genealogical periodicals.

Dr. G. W. COGGESHALL has resigned from the Emergency Fleet Corporation and has returned to the Institute of Industrial Research.

Dr. A. S. CUSHMAN has been honorably discharged as Lieutenant Colonel, Ordnance Department, U. S. A., and has returned from Frankford Arsenal, Philadelphia, to resume his former duties as director of the Institute of Industrial Research.

Mr. JOHN GAUB, in charge of the laboratories of the Filtration Plant, has resigned to become Health Officer and Examiner of Foods at Montclair, New Jersey.

Dr. D. R. HARPER, 3rd, physicist at the Bureau of Standards, and engaged in the personnel and employment work of the Bureau during the war, resigned at the close of the year and has joined the staff of the U. S. Bureau of Efficiency, where he will assist in the reorganization and expansion of the Internal Revenue Service.

Mr. M. D. HERSEY of the Bureau of Standards recently returned from an extended trip abroad. He spent several months in England, France and Italy, conferring with officials there in regard to the development of aeronautic instruments.

Professor A. S. HITCHCOCK, of the Bureau of Plant Industry, is chairman of the Committee on Nomenclature of the Botanical Society of America.

Mr. NEIL M. JUDD, of the department of anthropology, Smithsonian Institution, has been appointed curator of American archeology in the National Museum.

Dr. PAUL D. MERICA, associate physicist in the metallurgical division of the Bureau of Standards, has resigned from the Bureau and is with the International Nickel Company at Bayonne, New Jersey.

Dr. P. W. MERRILL has resigned his position at the Bureau of Standards to take up scientific work at the Mt. Wilson Solar Observatory of the Carnegie Institution of Washington, at Pasadena, California.

Professor C. K. LEITH, professor of geology at the University of Wisconsin, and member of the Shipping Board, sailed for France early in January to join the American peace delegation.

Dr. WALLACE CLEMENT SABINE, professor of physics at Harvard University, died at his home on November 11, 1918. He had been located in Washington during the war as Director of the Section of Technical Information of the Bureau of Aircraft Production.

Professor T. T. SMITH of the University of Kansas, who has been in charge of the work on optical instruments and the testing of optical glass at the Bureau of Standards for the past year, has returned to the University.

Mr. H. F. STALEY, formerly professor of ceramic engineering at Iowa State College, joined the staff of the Bureau of Standards in December as metallurgical ceramist. Mr. Staley had been engaged in war research at the Bureau since June, 1918.

Lieut. D. L. WEBSTER, formerly with the National Research Council, has returned to the department of physics of the University of Michigan.

Dr. EDGAR T. WHERRY, of the Bureau of Chemistry, U. S. Department of Agriculture, has been appointed editor-in-chief of *The American Mineralogist*. Among the associate editors is Dr. W. T. SCHALLER, of the U. S. Geological Survey.

Major F. E. WRIGHT, of the Ordnance Department (formerly of the Geophysical Laboratory, Carnegie Institution), has been elected president of the Optical Society of America.